

Chapter 5

Comparing Strategies for Improving System Performance

“The basic idea is to define alternatives to just sufficient a level of detail to allow different stakeholders to at least rank order them in terms of desirability according to each identified criterion.”

Theodor J. Stewart, “Thirsting for Consensus”

Carl D. Martland, *Toward More Sustainable Infrastructure*

Methodologies for Comparing Strategies

- Presenting all results in monetary terms
- Discounting and net present value
- Cost effectiveness
- Weighting schemes
- Public input

Presenting All Results in Monetary Terms

- Benefits: easily understood
- Readily applicable to both financial and economic benefits
- Dangers:
 - No standard ways to value many costs and benefits
 - Temptation to disregard costs and benefits that are difficult to value, including equity and aesthetics

Comparing Current and Future Values

- Costs and benefits will be spread out over decades
- Large investments over the near term must be justified by benefits received over the long term
- **DISCOUNTING** is a way to compare present and future benefits: “discounting” means that future values will count for less – they are “discounted”

Future values must be discounted to present values!

Calculating the Present Value

$$\text{Present value} = \text{Future Value} / (1+r)^t$$

Net Present Value

- NPV is the sum of all of the discounted costs and benefits associated with a project.
- If NPV is greater than 0, then the monetarized benefits outweigh the costs.
- The higher the NPV, the better (from a financial or economic point of view).
- Goal in the private sector:

Maximize the NPV of Cash Flows

Return on Investment (ROI)

- If an investment I is made at time 0 and the net financial profit in year t is $P(t)$, then the return on investment in year t is:

$$\text{ROI}(t) = P(t)/I$$

- Profit - and therefore ROI – generally varies from year to year. If profit is constant:

$$P(t) = P \text{ for all years } t$$

$$\text{ROI}(t) = P/I \text{ for all years } t$$

How Much Investment is Justifiable?

- Suppose a project is expected to have constant profit P over an infinite time horizon. How much investment can we justify?
- Assumption: use our **minimum acceptable rate of return (MARR)** as the discount rate
- The maximum investment is determined as the amount M such that $ROI = MARR$:

$$ROI = P/M = MARR \text{ so that } M = P/MARR$$

- The NPV of the project is the difference between the maximum we would be willing to invest and the actual amount I that we would be required to invest:

$$NPV = M - I = P/MARR - P/ROI$$

where ROI in this equation is P/I , the expected ROI for the project

Value of an Infinite Stream of Constant Benefits

$$\text{NPV} = \text{Annual Benefit} / \text{Discount Rate}$$

Example

- Assumptions about a proposed busway:
 - Investment: \$200 million
 - Annual net benefits: \$15 million
 - Government agency's discount rate: 7%
- Comparing the NPV of benefits to the investment shows that the project is worth pursuing (from a financial perspective):

$$\text{NPV of benefits} = \$15 \text{ million} / 0.07 = \$214 \text{ million}$$

$$\text{NPV of project} = \$214 \text{ million} - \$200 \text{ million} > 0$$

Choice of a Discount Rate

- High discount rates favor projects with low investment and immediate benefits
- Low discount rates favor larger projects with longer term payouts
- Typical discount rates:
 1. Private sector: 10% or more (and much more for risky projects)
 2. Local, state and federal governments: less than private sector only because governments do not pay taxes (7% would be equivalent to 10% pre-tax for the private sector)
 3. If a special agency such as a port authority raises money by selling bonds (rather than through taxation), the discount rate can be as low as the interest rate on the bonds

Cost Effectiveness

- Consider several options that are designed to seek improvements in performance that are readily measured, but not in monetary terms.
- Cost effectiveness can be defined as:

Cost effectiveness of option $k = \Delta P(k)/I$

where

$\Delta P(k)$ = change in performance of option k

$I(k)$ = investment required for option k

Cost Effectiveness for Three Options for Reducing Noise Levels

Option	Cost	Reduction in Noise Levels	Cost-Effectiveness (\$/% improvement)
Noise barrier	\$500,000	20%	\$25 thousand
Sound-Proofing	\$200,000	22%	\$9.1 thousand
Redesign floor space	\$100,000	21%	\$4.8 thousand

Multi-Criteria Decision-Making

- Reality:
 - Major projects have multiple objectives, many of which cannot be measured in monetary terms
 - Competing designs will have markedly different performance for the various criteria
- Decisions must reflect multiple criteria:
 - Ultimately a “political” judgment – people with varying backgrounds, interests, and agendas will have to figure out how to decide
 - Weighting schemes can be useful – but they are not “objective”

Situation in Which Weighting Systems Can Be Most Useful

- General agreement concerning:
 - The options to be considered
 - The relevant criteria
 - How these criteria should be measured
 - The relative importance of the options
- Groups involved in the decision are not already committed to specific, conflicting options

Role of the Analyst

- Provide the best information possible within the available time and budget
- Identify what is certain, what is likely, and what is possible
- Explain how much faith you put in the assumptions and the methodologies that have been used
- Make sure that the range of options is wide enough to cover the major strategies that you believe are worthy of consideration
- Ensure that the public discussion deals with actual data and credible options
- Provide insight into cost-effectiveness of proposals with respect to various criteria

Expanding Capacity of a Bus System: Predicted Cost and Performance

	Cost (Mill.)	Improved Travel Times	Increased Ridership	Reduced Emissions/ Bus-Mile	Families & Businesses to Relocate
Buy 100 new buses	\$50	5%	20%	10%	10
Buy 75 new hybrid Buses	\$60	4%	15%	40%	10
Create a busway	\$200	20%	30%	8%	30
Install a control System	\$20	10%	5%	5%	0

Expanding Capacity of a Bus System: Ordinal Rankings: Buy buses!

	Cost (Mill.)	Improved Travel Times	Increased Ridership	Reduced Emissions/ Bus-Mile	Families & Businesses to Relocate	Total
Buy 100 new buses	2	3	2	2	2	11
Buy 75 new hybrid Buses	3	4	3	1	2	13
Create a busway	4	1	1	3	3	12
Install a control System	1	2	4	4	1	13

Expanding Capacity of a Bus System:
**Heavier Weights for Capacity &
 Ridership: Build the Busway!**

	Cost (Mill.)	Improved Travel Times	Increased Ridership	Reduced Emissions/ Bus-Mile	Families & Businesses to Relocate	Total
Weight :	1	3	3	1	1	
Buy 100 new buses	2	3x3	2x3	2	2	21
Buy 75 new hybrid Buses	3	4x3	3x3	1	2	27
Create a busway	4	1x3	1x3	3	3	16
Install a control System	1	2x3	4x3	4	1	24

Expanding Capacity of a Bus System:
**Heavier Weights for Cost & Ridership;
 Ignore Relocation: Buy the Buses!**

	Cost (Mill.)	Improved Travel Times	Increased Ridership	Reduced Emissions/ Bus-Mile	Families & Businesses to Relocate	Total
Weight	2	1	2	1	0	
Buy 100 new buses	2x2	3	2x2	2	0	13
Buy 75 new hybrid Buses	3x2	4	3x2	1	0	17
Create a busway	4x2	1	1x2	3	0	14
Install a control System	1x2	2	4x2	4	0	16

**Expanding Capacity of a Bus System:
 Normalize Relative to the Best Option;
 Ignore Relocation: Buy Hybrid Buses!**

	Cost (Mill.)	Improved Travel Times	Increased Ridership	Reduced Emissions/ Bus-Mile	Total
Weight	2	1	2	1	
Buy 100 new buses	50/20 = 2.5	20%/5% = 4	30%/20% = 1.5	40%/10% = 4	12
Buy 75 new hybrid Buses	60/20 = 3	20%/4% = 5	30%/15% = 2	40%/40 = 1	11
Create a busway	200/20 = 10	20%/20% = 1	30%/30% = 1	40%/8% = 5	17
Install a control System	20/20 = 1	20%/10% = 2	30%/5% = 6	40%/5% = 8	17

Increase the Capacity of a Bus System: Lessons Learned

- It is impossible to define a “correct scheme”
 - Competing options
 - Multiple objectives
 - Different priorities among groups participating in the decision
- Some sort of participatory process will be needed to reach a consensus
- Further analysis, continued discussion and public input may be desirable
- At some point, whoever is really in charge may just have to make a decision (whether that is a company CEO, congress, the mayor or a court)

Case Study: Integrated Coastal Zone Management Strategy for Ghana

- Situation: coastal zone has only 6.5% of land in Ghana, but 25% of the population
- Problems:
 - Poor health
 - Poverty
 - Environmental degradation from development
- Study: World Bank and EPA Ghana
- Objective: *“Identify economically, socially environmentally appropriate interventions and projects in the coastal zone that improve the prospects for human development”*

“Integrated Coastal Zone Management Strategy for Ghana”, **Findings 113**,
World Bank for Reconstruction and Development, June 1998

Summary of Regional Environmental Priorities Within Ghana's Coastal Zone

Environmental Problem	Western Region	Central Region	Accra Urbanized Area	Volta Delta
Domestic sanitation	Moderate	High	High	High
Fisheries degradation	Low	Low	High	Moderate
Wetland and mangrove degradation	Moderate	Low	Moderate	Moderate
Industrial pollution	Moderate	Low	Moderate	Low
Erosion	Low	Low	Low	Moderate
Forest degradation	Moderate	Moderate	Low	Moderate
Aquatic weed development	Low	Low	Low	Low

Four Categories of Intervention within Ghana's Coastal Zone

- Direct investments in new construction or upgrading technology
- Economic or regulatory incentives, including taxes, subsidies, and licenses
- Education initiatives to promote
 - Better management
 - Increased knowledge and awareness of problems
- Institutional or policy reforms

Criteria Used to Weight Benefits of Options of Each Strategy

- Reduction of the extent of the problem
- Improved ecosystem health
- Improved human health
- Reduced risk of extinctions
- Reduced incidence of toxic and hazardous substances
- Improved economic efficiency

Measuring Cost Effectiveness

- Costs and impacts were normalized for a standard population of 100,000
 - Cost per person
 - Impact for the region (scale of 1 to 10)
- Cost effectiveness measured as the normalized cost per person divided by the average impact
- Cost effectiveness given as:
 - High ($CE < 1$)
 - Medium ($1 < CE < 2.5$)
 - Low ($CE > 2.5$)
- Although quite qualitative, this methodology was able to identify the most promising strategies for Ghana's coastal zone

Cost Effectiveness of Selected Strategies

Intervention Category	Domestic Sanitation	Wetland & Mangrove Degradation	Industrial Water Pollution
Direct Investment	Small-scale Waste collection H	Mangrove planting H	Process modifications H
	Constructed wetlands M	Sensitivity mapping H	Secure landfills M
	Centralized Waste treatment L	Protected area acquisition H	Centralized treatment L
	Large-scale treatment L		
Incentives	Regulatory enforcement H	Regulatory reforms H	Incentives H
	Fines & user charges H	Biodiversity strategy H	Regulatory reforms M
	Payments and subsidies H	Management plans H	Pollution Fines M

Scenario-Based Planning

- Initial problem structuring
- Screening analysis
- Assessment and ranking of scenarios
- Refinement of the scenarios or of the problem definition
- Ranking of options using each groups weighting preferences

Source: Theodor J. Stewart, "Thirsting for Consensus"

Case Study:

Scenario-Based Planning in South Africa

- Proposed project: North East Cape Forests (NECF) wanted to expand an existing forestry operation to achieve economic sustainability
- Local objections:
 - Concerns about loss of virgin grasslands
 - Need to conserve water
 - Impacts on wildlife
- Regulatory requirement: permit needed from National Dept. of Water Affairs and Forestry (DWAF) in order to plant new forests

Case Study:

Scenario-Based Planning in South Africa

- Motivation for study:
 - NECF frustrated by regulatory delay
 - Scenario-Based Planning seen as means of achieving consensus about what to do
- Approach
 - Workshops attended by NECF and DWAF officials, conservation groups, local government officials, hydrologists
 - Addressed “how to develop an overall plan” rather than looking at specifics of several proposed plots for the new forest

Case Study:

Scenario-Based Planning in South Africa

- Elements of scenarios
 - How much land to use for commercial forestry
 - Whether to process logs in local saw mills, a centralized mill in the region, or in a mill somewhere outside of the region
- Six scenarios defined, plus the status quo
- After review of the options, the group eliminate two and asked for more detail on others:
 - Location and extent of planting
 - Sensitivity of areas to environmental concerns

Case Study:

Scenario-Based Planning in South Africa

- Conclusion of additional study:
 - Development within any of the originally proposed areas would be acceptable, so long as nothing was down in the most environmentally sensitive areas
- Consensus conclusion of workshop:
 - Develop entire amount requested by NECF
 - Restrict development in sensitive areas
 - Process logs at a single new saw mill within the region
- DWAR issued permits close to what was recommended by the workshop participants



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